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FORM PTO-1390 (REV 5-93)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE ATTORNEY'S DOCKET NUMBER	
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		FCCC 96-11	
		U.S. APPLICATION NO. (PCT/PTO 371C F. 1.5) 09/202549	
INTERNATIONAL APPLICATION NO. PCT/US97/10486	INTERNATIONAL FILING DATE 17 June 1997	PRIORITY DATE CLAIMED 17 June 1996	
TITLE OF INVENTION NUCLEIC ACID MOLECULE FOR ENHANCING GENE EXPRESSION			
APPLICANT(S) FOR DO/EO/US Philip TSICHLIS, H. Leighton GRIMES and Patrick ZWEIDLER-McKAY			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
<ol style="list-style-type: none"> 1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371. 2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371. 3. <input checked="" type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1). 4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date. 5. <input type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)) <ol style="list-style-type: none"> a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau). b. <input type="checkbox"/> has been transmitted by the International Bureau. c. <input checked="" type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US) 6. <input type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)). 7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) <ol style="list-style-type: none"> a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau). b. <input type="checkbox"/> have been transmitted by the International Bureau. c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired. d. <input type="checkbox"/> have not been made and will not be made. 8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)). 			
Items 11. to 16. below concern other document(s) or information included:			
<ol style="list-style-type: none"> 11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. <input type="checkbox"/> A FIRST preliminary amendment. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment. 14. <input type="checkbox"/> A substitute specification. 15. <input type="checkbox"/> A change of power of attorney and/or address letter. 16. <input checked="" type="checkbox"/> Other items or information: <ol style="list-style-type: none"> 1. Copy of Verified Statement (Declaration) Supporting Another's Claim for Small entity Status [37 CFR 1.9(f) and 1.27(d)] - Nonprofit Organization from U.S. Provisional Application No. 60/019,808 2. Certificate of Express Mailing Under 37 CFR 1.10 			

U.S. APPLICATION NO./IF known, see 37 CFR 1.50		INTERNATIONAL APPLICATION NO. PCT/US97/10486		ATTORNEY'S DOCKET NUMBER	
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<p>17. <input type="checkbox"/> The following fees are submitted:</p> <p style="margin-left: 20px;">Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO..... \$830.00</p> <p style="margin-left: 20px;">International preliminary examination fee paid to USPTO (37 CFR 1.482) \$640.00</p> <p style="margin-left: 20px;">No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)).. \$710.00</p> <p style="margin-left: 20px;">Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO..... \$950.00</p> <p style="margin-left: 20px;">International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)..... \$90.00</p> <p style="text-align: right; margin-right: 20px;">ENTER APPROPRIATE BASIC FEE AMOUNT =</p> <p>Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <th style="width: 15%;">Claims</th> <th style="width: 20%;">Number Filed</th> <th style="width: 20%;">Number Extra</th> <th style="width: 15%;">Rate</th> <th style="width: 15%;"></th> <th style="width: 15%;"></th> </tr> <tr> <td>Total claims</td> <td>25 -20 =</td> <td>5</td> <td>X 18.00</td> <td>\$ 90</td> <td>00</td> </tr> <tr> <td>Independent Claims</td> <td>5 -3 =</td> <td>2</td> <td>X 78.00</td> <td>\$ 156</td> <td>00</td> </tr> <tr> <td colspan="4">Multiple dependent claims(s) (if applicable)</td> <td>+</td> <td>\$</td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL OF ABOVE CALCULATIONS</td> <td>=</td> <td>\$ 472 00</td> </tr> <tr> <td colspan="4">Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).</td> <td>\$ 236</td> <td>00</td> </tr> <tr> <td colspan="4" style="text-align: right;">SUBTOTAL</td> <td>=</td> <td>\$ 236 00</td> </tr> <tr> <td colspan="4">Processing fee of \$130.00 for furnishing the English translation later the <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).</td> <td>+</td> <td>\$</td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL NATIONAL FEE</td> <td>=</td> <td>\$ 236 00</td> </tr> <tr> <td colspan="4">Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +</td> <td>\$</td> <td></td> </tr> <tr> <td colspan="4" style="text-align: right;">TOTAL FEES ENCLOSED</td> <td>=</td> <td>\$ 236 00</td> </tr> <tr> <td colspan="4"></td> <td style="text-align: right;">Amount to be:</td> <td></td> </tr> <tr> <td colspan="4"></td> <td style="text-align: right;">refunded</td> <td>\$</td> </tr> <tr> <td colspan="4"></td> <td style="text-align: right;">charged</td> <td>\$</td> </tr> </table> <p>a. <input checked="" type="checkbox"/> A check in the amount of \$ <u>236.00</u> to cover the above fees is enclosed.</p> <p>b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.</p> <p>c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>04-1406</u>. A duplicate copy of this sheet is enclosed.</p> <p>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</p> <div style="display: flex; justify-content: space-between; margin-top: 20px;"> <div style="width: 60%;"> <p>SEND ALL CORRESPONDENCE TO:</p> <p>Janet E. Reed, Ph.D. DANN, DORFMAN, HERRELL AND SKILLMAN 1601 Market Street Suite 720 Philadelphia, PA 19103-2307</p> </div> <div style="width: 35%; text-align: center;"> <p style="margin: 0;">SIGNATURE</p> <p style="margin: 0;">Janet E. Reed, Ph.D.</p> <p style="margin: 0;">NAME</p> <p style="margin: 0;"><u>36,252</u></p> <p style="margin: 0;">REGISTRATION NUMBER</p> </div> </div>	Claims	Number Filed	Number Extra	Rate			Total claims	25 -20 =	5	X 18.00	\$ 90	00	Independent Claims	5 -3 =	2	X 78.00	\$ 156	00	Multiple dependent claims(s) (if applicable)				+	\$	TOTAL OF ABOVE CALCULATIONS				=	\$ 472 00	Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				\$ 236	00	SUBTOTAL				=	\$ 236 00	Processing fee of \$130.00 for furnishing the English translation later the <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				+	\$	TOTAL NATIONAL FEE				=	\$ 236 00	Fee for recording the enclosed assignment (37 CFR 1.21(h)). 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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant or Patentee: Philip Teichlis, M. Leighton Grimes and Patrick A. Zweidler-McKay

Provisional Application or Patent No.: Not yet Assigned

Filed or Issued: Concurrently Herewith

For: NUCLEIC ACID ENCODING RECOMBINANT PROMOTER SEQUENCES AND METHOD OF USE THEREOF

**VERIFIED STATEMENT (DECLARATION) SUPPORTING ANOTHER'S CLAIM FOR
SMALL ENTITY STATUS (37 CFR §1.91(f) AND §1.27(d)) - NONPROFIT ORGANIZATION**

I hereby declare that I am making this verified statement to support a claim by the above-identified applicant or patentee for small entity status for purposes of paying reduced fees with regard to the above-identified invention described in

- ☒ the specification filed herewith
☐ U.S. Application No. _____, filed _____
☐ U.S. Patent No. _____, issued _____

I hereby declare that I am an official empowered to act on behalf of the nonprofit organization identified below:

FULL NAME OF ORGANIZATION:

FOX CHASE CANCER CENTER

ADDRESS OF ORGANIZATION:

7701 Burholme Avenue
Philadelphia, PA 19111

TYPE OF ORGANIZATION

- ☒ University or other institution of Higher education
☐ Tax exempt under U.S. Internal Revenue Code [26 USC§501(c) and
☐ Nonprofit scientific or educational under statute of state of U.S.A.
Name of State:
Citation of Statute:
☐ Would qualify as tax exempt under U.S. IRC if located in U.S.A.
☐ Would qualify as nonprofit scientific or educational under statute of
state of U.S.A if located in U.S.A.

Name of State:
Citation of Statute:

I hereby declare that the nonprofit organization identified above qualifies as a nonprofit organization as defined in 37 CFR §1.9(e) for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code to the above-identified invention.

I hereby declare that rights under contract or law have been conveyed to and remain with the nonprofit organization with regard to the above-identified invention.

If the rights held by the nonprofit organization are not exclusive, each individual, concern or organization known to have rights to the invention is listed below* and the organization knows of no rights to the invention being held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR §1.9(c) if that person had made the invention, or by any concern which would not qualify as a small business concern under 37 CFR §1.9(d) or by a nonprofit organization under 37 CFR §1.9(e).

FULL NAME:

ADDRESS:

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME:

ADDRESS:

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

FULL NAME:

ADDRESS:

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

* NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR §1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate (37 CFR §1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Person Signing: Patricia Hersche

Title in Organization: Vice President, Business Development and Regulatory Affairs

Address: 7701 Burholme Avenue, Philadelphia, PA 19111

Signature: *Patricia Hersche*

Date: 6/17/96

09/202549

NUCLEIC ACID MOLECULE FOR ENHANCING GENE EXPRESSION

Pursuant to 35 U.S.C. §202(c), it is hereby acknowledged that the U.S. Government has certain rights in the invention described herein, which was made in part
5 with funds from the National Institutes of Health, Grant No. 01CA56110.

FIELD OF THE INVENTION

This invention relates to the field of
10 recombinant DNA technology. More specifically, the invention pertains to DNA constructs and methods for enhancing gene expression to produce clinically beneficial proteins in transformed cells.

15 BACKGROUND OF THE INVENTION

Several publications are referenced in this application by numerals in parentheses in order to more fully describe the state of the art to which this invention pertains. Full citations for these references
20 are found at the end of the specification. The disclosure of each of these publications is incorporated by reference herein.

Advances in the field of molecular biology over the last two decades have made possible the
25 identification and detailed study of genetically significant regions of specific DNA molecules.

For a gene to be transcribed it is necessary for specific protein factors known as transcription factors to bind particular sites in the regulatory
30 regions of the gene to induce its transcription by the enzyme RNA polymerase. Certain transcription factors, such as TFIID, are constitutively expressed and are required for the assembly of a basal, stable transcription complex.

35 A promoter is a specific DNA sequence that signals where RNA synthesis should begin. The level of

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transcription directed by the basal transcriptional complex bound at the promoter is greatly enhanced by the binding of other constitutively expressed factors to upstream promoter elements which are usually located immediately upstream of the promoter itself. In addition, however, many genes contain other regulatory DNA sequences, which are interdigitated with the upstream promoter elements and which bind transcription factors that only become active in specific cell types or in response to a particular signal. Thus, the presence of such sequences can confer a specific expression pattern on a particular gene.

The transcription of eucaryotic genes can also be regulated by more distant elements known as enhancers. Enhancers contain binding sites for the same constitutively expressed or tissue-specific regulatory factors which bind immediately upstream of the promoter but often contain multiple copies of the binding site or sites for many different factors. Although the enhancer cannot drive transcription itself, it can enhance the activity of the promoter by several orders of magnitude. Such enhancement may occur in all cell types if the enhancer contains binding sites for constitutively expressed transcription factors or may occur only in specific tissue or in response to a specific signal if the enhancer contains binding sites for factors which are involved in gene regulation.

Although most constitutively expressed or regulated transcription factors activate the transcription of specific genes, it is also possible for transcription to be specifically inhibited by the action of transcription factors. One mechanism by which a factor can inhibit gene expression is by preventing the binding to DNA of another activating factor. Another mechanism involves the negative factor binding to the already DNA-bound activating factor resulting in a masking of the activation domain. Finally, some negative

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factors can inhibit gene expression directly. Regardless of the molecular mechanism, the binding of such factors to DNA results in the repression of transcription. In situations requiring maximal gene expression of a protein of interest, identification of these negative sites in relevant promoter regions is highly desirable.

DNA vectors (i.e., plasmids, viruses) can be modified to include a gene for a foreign protein. Some of these recombinant vectors contain a promoter/enhancer necessary for the expression of the gene upstream from what is known as a cloning site. (i.e., a rare or unique restriction enzyme site where a foreign gene of interest can be inserted). The recombinant expression vectors can then be transfected into cells or tissues where the foreign gene is to be expressed.

Such expression vectors are of great value for the purposes of creating transgenic animals and for use in gene therapy. Current strategies involving gene therapy seek to first identify the defective gene, and then to supplement the defective tissues with the functional gene. Transgenic animals and gene therapy are only two examples of the wide range of uses for expression vectors in biology and medicine. Expression vectors also have many *in vitro* uses, such as permitting production of large amounts of a protein of interest.

Viral recombinant promoter elements are currently the most widely used in the construction of recombinant vectors. Typically, they are derived from pathogenic viruses such as Epstein Barr Virus (EBV), Rous Sarcoma Virus (RSV), Simian Virus 40 and Human Cytomegalovirus (CMV). While generally effective, in some cases viral promoters are "turned off" or repressed after a time when in a eucaryotic host.

Accordingly, there is a need for the identification of sequences required for the binding of the above-mentioned putative transcriptional repressors. Identification and elimination of these repressor binding

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sites in viral or cellular promoter sequences will facilitate the development of recombinant vectors for use *in vitro* and in gene therapy that demonstrate enhanced gene expression and measurable increases in the production of the encoded, clinically beneficial proteins.

SUMMARY OF THE INVENTION

The present invention provides DNA constructs, expression vectors and methods for their use in augmenting gene expression in cultured cells and in animals, including humans. The DNA constructs and vectors of the invention are used beneficially in gene therapy and for the production of DNA vaccines.

In accordance with the present invention, an isolated DNA construct is provided, which comprises at least one mutated binding site for a Gfi-1 transcription repressor. The mutated binding site comprises a mutation which hinders or prevents binding of Gfi-1 to the site. The mutated binding site preferably is disposed within an expression regulatory segment, such as a promoter or enhancer, and most preferably within a mammalian cellular promoter or a viral promoter, such as a human cytomegalovirus (CMV) promoter.

In a preferred embodiment, the aforementioned Gfi-1 binding site, prior to mutation, is at least 65% (more preferably at least 79%, and most preferably at least 98%) homologous with a sequence comprising N_1 AAATCAC N_2 GCA (Sequence I.D. No. 1), wherein N_1 and N_2 are any nucleotide, but preferably N_1 is T and N_2 is A or T (Sequence I.D. No. 2 is the preferred sequence, TAAATCAC(T/A)GCA). In a particularly preferred embodiment, the mutation is in that portion of the binding site having the sequence AATC.

According to another aspect of the invention, the DNA construct disposed within an expression regulatory segment is operably linked to a coding

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segment. The coding segment preferably encodes gene products such as cytokines, interleukins, interferons, growth factors and signalling proteins involved in regulation of cell growth (oncogenes).

5 According to another aspect of the invention, an expression regulatory DNA segment is provided which comprises at least one copy of a sequence at least 65% (more preferably at least 79% and most preferably at least 98%) homologous with the sequence N₁A-R-CN₂AGCA
 10 (Sequence I.D. No. 3). Here, N₁ and N₂ are any nucleotide, with preferred designations as described above, and R is a tetranucleotide selected from the group consisting of:

N₃ATC, AN₄TC, AAN₅C, AATN₆
 15 N₃N₄TC, N₃AN₅C, N₃ATN₆, AN₄N₅C, AN₄TN₆, AAN₅N₆
 N₃N₄N₅C, N₃N₄TN₆, N₃AN₅N₆, AN₄N₅N₆, and N₃N₄N₅N₆,
 wherein N₃ is G, C or T, or is absent, or is an oligonucleotide of two or more nucleotides; N₄ is G, C or T, or is absent, or is an oligonucleotide of two or more
 20 nucleotides; N₅ is A, G or C, or is absent, or is an oligonucleotide of two or more nucleotides; and N₆ is A, G or C, or is absent, or is an oligonucleotide of two or more nucleotides. In a preferred embodiment, the expression regulatory segment is a promoter, most
 25 preferably a mammalian cellular promoter or a viral promoter, such as a CMV promoter.

According to another aspect of the invention, the aforementioned expression regulatory sequence is provided in an expression vector, which also contains an
 30 operatively positioned insertion site for insertion of a coding segment. In a preferred embodiment the coding segment encodes gene products such as cytokines, interleukins, interferons, growth factors or signalling proteins involved in regulation of cell growth
 35 (oncogenes).

According to another aspect of the invention, a mutant promoter is provided, which comprises two mutated

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Gfi-1 binding sites. This promoter is derived from the CMV-MIE wildtype promoter (Sequence I.D. No. 12), and comprises sequences such as those exemplified by, but not limited to, Sequence I.D. No. 13 or Sequence I.D. No. 14, both of which contain mutations in the two naturally occurring Gfi-1 binding sites found in the wildtype promoter. This promoter is preferably contained within an expression vector.

According to yet another aspect of the present invention, methods are provided for improving the expression of genes regulated by expression regulatory sequences that contain binding sites for the Gfi-1 transcription repressor. The methods comprise altering the sequence of the Gfi-1 binding sites in the regulatory segments, so as to hinder or prevent binding of Gfi-1 to those sites, thereby improving expression of the genes.

The present invention facilitates maximized exogenous gene expression by expression regulatory segments (such as the CMV-MIE promoter) containing recombinant vectors in cells. Such vectors can be used to direct expression of any gene. Vectors containing a foreign gene of interest under the regulation of the promoter are administered to cells of a living organism under conditions whereby the vector enters cells and expresses the protein encoded by the gene of interest. Such gene expression can occur without repression by Gfi-1 in the cells, since the promoter contains mutated Gfi-1 binding sites to which the transcription repressor cannot bind.

According to another aspect of the present invention, a method is provided for treating a pathological condition related to the expression of an aberrant gene. The method comprises administering to a patient having such a pathological condition a pharmaceutical preparation comprising a vector of the invention, as described above, capable of entering a cell expressing the aberrant gene. Expression of the normal

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gene results in production of a functional gene product, thereby alleviating the pathological condition.

According to another aspect of this invention, a pharmaceutical preparation is provided for treating a pathological condition related to the aberrant gene expression. This pharmaceutical preparation comprises, in a biologically compatible medium, a vector of the invention, as described above, encoding a gene of interest capable of entering a cell, and expressing the protein encoded thereby. Incorporation of the DNA constructs of the invention into suitable recombinant vectors for delivery via liposomes is also contemplated to be within the scope of this invention.

The DNA expression vector encoding the gene of interest is synthesized so as to be capable of crossing a biological membrane in order to enter cells and thereafter express the protein encoded by the gene of interest. A biologically compatible medium is preferably formulated to enhance the lipophilicity and membrane-permeability of the expression vector.

In yet another preferred embodiment, the DNA constructs and the vectors of the invention may also be used alone or in combination with chemotherapeutic drugs to treat bone marrow or peripheral stem cell grafts of cells. They may also be used to deliver DNA vaccines.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a segment of DNA containing the deduced Gfi-1 binding site (Sequence I.D. No. 4), deduced by PCR amplification of a random library. The AATC motif is underlined.

Figure 2 is a composite of data illustrating the significance of specific bases on Gfi-1/DNA binding. Figure 2A is an autoradiogram of DNase I footprint analysis using recombinant GST/Gfi-1 protein and near consensus oligonucleotide. Figure 2B is an autoradiogram showing the results of DMS methylation interference.

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This identifies the bases in both DNA strands that come in contact with the GST-Gfi-1 fusion protein. Figure 2C (Sequence I.D. No. 5) shows the combined data from figures 2A and 2B. The solid line indicates the extent of the DNA footprint. The circles above identify individual bases that are in contact with the protein. Figure 2D1 shows the mutant binding sites of the oligonucleotides. R21 is Sequence I.D. No. 6; R21A is Sequence I.D. No. 7; R21B is Sequence I.D. No. 8; R21C is Sequence I.D. No. 9; R21D is Sequence I.D. No. 10; and R21E is Sequence I.D. No. 11. Figure 2D2 is an autoradiogram of EMSA performed on the oligonucleotides of Figure 2D1. Figure 2D3 is a histogram quantitating the results in Figure 2D2. Figure 2E illustrates that Gfi-1 from transfected COS-1 nuclear extracts binds oligonucleotides encoding the R21 binding site but not to the mutant site, i.e., R21A.

Figure 3A shows the nucleic acid sequence of the HCMV-MIE promoter (Sequence I.D. No. 12). The two putative Gfi-1 binding sites are boxed. The four 18 bp repeats are underlined. CAAT and TATA boxes are shown with a double underline. The major transcription start site is indicated by +1. Figure 3B shows the nucleotide sequence of the two potential Gfi-1 binding sites (as shown in Sequence I.D. No. 12) compared to the Gfi-1 binding consensus sequence (Sequence I.D. No. 1). Figure 3C shows the nucleotide changes in the mutated Gfi-1 binding sites in the CMV-MIE promoter. Mutant A is Sequence I.D. No. 13 and Mutant B is Sequence I.D. No. 14. Figure 3D is a graph showing the relative CAT activity in extracts of NIH-3T3 cells transfected with wild type and mutant HCMV-MIE promoter/CAT reporter constructs in the presence or absence of Gfi-1.

Figure 4 shows a schematic representation of the contacts between Gfi-1 amino acids and the nucleotides of the binding site.

DETAILED DESCRIPTION OF THE INVENTION**A. Definitions**

The nucleic acids of the invention are sometimes referred to herein as "isolated nucleic acids".

5 This term, when applied to DNA, is intended to signify a DNA molecule that is separated from sequences with which it is immediately contiguous (in the 5' to 3' directions) in the naturally occurring genome of the organism from which it was derived. For example, the "isolated nucleic acids" of the invention may comprise a DNA molecule
10 inserted into a vector, such as a plasmid or a virus vector, or integrated into the genomic DNA of an organism. With respect to RNA molecules, the term "isolated nucleic acids" primarily refers to RNA
15 molecules encoded by isolated DNA molecules as defined above, or produced by synthetic methods.

The terms "transcription control element" and "expression regulatory segment" are used interchangeably herein, and refer to an isolated DNA segment that, under
20 specified conditions, possesses a transcription-regulating activity with respect to the expression of a coding segment that encodes a gene product. Expression regulatory segments include promoters, enhancers, internal elements and 3' regulatory segments.

25 The term "transcription factor" refers to protein factors that interact with DNA to enhance or repress transcription.

The term "repressor" refers to a transcription factor that inhibits gene expression upon interaction
30 with DNA.

The term "transcription unit" refers to a nucleic acid molecule comprising one or more sequences (referred to herein as a "coding segment") that encodes a gene product (usually a protein) and is operably linked
35 to a promoter or other expression regulatory sequences (as defined above) necessary for expression of the coding

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sequence. The term "gene" is often used interchangeably with the term "transcription unit".

The term "operably linked" or "operably positioned" means that the regulatory segments necessary for expression of the coding segment are placed in the DNA molecule in the appropriate positions relative to the coding sequence so as to effect expression of the coding sequence.

The term "gene therapy" refers to methods for augmenting levels of an expressed gene or replacing a defective gene via delivery of the vectors of the invention containing the gene of interest to specified cell types or tissues.

When used herein in describing DNA fragment lengths or other experimental results, the term "approximately" means within a margin of commonly acceptable error for the determination being made, using standard methods (e.g., agarose gel electrophoresis and comparison with DNA molecules of known size to determine DNA fragment size or relative position).

When referring to specific nucleic acid sequences set forth herein, the term "substantially the same as" means taking into account minor variations or substitutions that arise for a number of reasons, but do not alter the overall characteristics of the DNA molecule defined by the sequence. For example, homologous regions isolated from different species, sub-species or strains of an organism may possess sequence polymorphisms that render those sequences substantially the same as, but not identical to, the sequences set forth herein. With respect to the nucleic acids, substantial similarity is generally determined by sequence homology. Accordingly, the present invention is intended to encompass all sequences that are "substantially the same" as the sequences exemplified herein, within the confines of appropriate levels of sequence homology. Specifically, the invention is intended to encompass isolated nucleic

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acid molecules having at least about 65% (preferably at least 80%, and most preferably at least 90%) sequence homology with the exemplified sequences, unless otherwise specified.

5

B. Description

The growth factor independence-1, (Gfi-1) gene encodes a zinc finger protein with six C₂H₂ type C-terminal zinc finger motifs. Gfi-1 is a nuclear protein which binds DNA in a sequence specific manner, and functions as a transcriptional repressor. DNA binding is mediated by three of the six Gfi-1 zinc fingers. Gfi-1 binding to DNA, *in vitro*, generates a 21 bp footprint which extends over the 12 bp binding site, N₁AAATCACN₂GCA (Sequence I.D.No. 1, wherein N₁ preferably is T and N₂ preferably is A or T). DMS methylation interference analysis identified nine bases that closely interact with the protein. Point mutations of the binding site diminished or abrogated Gfi-1 binding and confirmed the specificity of the site. Although methylation interference suggested that Gfi-1 binding depends on protein DNA contacts both within and outside the AATC core, electrophoretic mobility shift assays using oligonucleotides of the wild type or mutant binding sites showed that only residues within the AATC core are critical.

Among the genes whose promoters contain Gfi-1 binding sites are genes encoding various cytokines and other regulators of cellular proliferation and differentiation (Table II in the Examples below). The induction of Gfi-1 during T cell activation, and its upregulation by provirus insertion during oncogenesis are expected to repress the expression of such genes. Gfi-1, therefore, may contribute to T cell activation, a process characterized by sequential waves of expression of cytokine and other regulatory genes (17), by regulating their timely repression. Since the expression of such

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genes may induce growth arrest, differentiation, and apoptosis in certain cell types, their repression by Gfi-1 may also contribute to the process of oncogenesis.

The DNA constructs of the invention comprise
5 mutated Gfi-1 binding sites as described above, which are modified so that they are no longer recognized by the repressor for binding, and binding of the repressor is thereby eliminated. These mutated binding sites are preferably incorporated into vectors, such as plasmid or
10 viral vectors, such that they are operably linked to, and control the expression of, coding sequences contained within such vectors. Methods for the synthesis of such DNA constructs and the assembly of vectors for expression of coding sequences are well known in the art. They
15 include oligonucleotide or DNA synthesis, restriction enzyme digestion, annealing and ligation of nucleic acid fragments, and other common methods as described generally, for example, by Sambrook et al.

As discussed above, Gfi-1 binding sites have
20 been identified in several cellular and viral promoter sequences, and use of such promoters with mutated binding sites is preferred for practice of the invention. However, to the extent that Gfi-1 binding sites are also present in other expression regulatory sequences, e.g.,
25 enhancers, internal sequences or 3' sequences, mutants of these regulatory segments that do not bind Gfi-1 are also contemplated for use in the present invention. Elucidation of the Gfi-1 consensus binding sequence in accordance with the present invention enables
30 identification of such binding sites wherever they may occur in a DNA molecule, regardless of location.

One of the promoters containing Gfi-1 binding sites is the HCMV-MIE promoter, which regulates the expression of genes required for the initiation of HCMV
35 infection and probably the reactivation of HCMV from latency (18, 19). This promoter contains two sites with 79% and 80% homology to the Gfi-1 binding site consensus.

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HCMV-MIE promoter/CAT reporter constructs were downregulated when cotransfected with Gfi-1 in NIH 3T3 fibroblasts. Moreover, the Gfi-1 mediated repression of the MIE promoter was abrogated when the Gfi-1 binding sites were mutated.

This abrogation of Gfi-1 mediated repression can be used to advantage to enhance the expression of genes driven by the CMV-MIE promoter. Gene therapy approaches utilizing vectors containing the promoter operably linked to the coding region of a protein of interest followed by introduction into cells is expected to result in a measurable increase in protein expression.

The CMV-MIE promoter has been used frequently to drive expression of exogenous genes for *in vitro* use, for construction of DNA vaccines and for other forms of gene therapy. The current invention exemplifies the mutational analysis of DNA sequences in the CMV-MIE promoter. However, as mentioned, Gfi-1 binding sites are detectable in a variety of viral and cellular expression regulatory sequences, and mutation of such sites to hinder or prevent the binding of the Gfi-1 transcription repressor also results in increased expression of such genes.

The following examples, relating to identification of the Gfi-1 consensus binding sequence and mutation of these binding sites in the HCMV promoter, set forth the general procedures involved in practicing the present invention. To the extent that specific materials are mentioned, it is merely for the purposes of illustration and is not intended to limit the invention. Unless otherwise specified, general cloning and other recombinant DNA procedures are used, such as those set forth in Molecular Cloning, Cold Spring Harbor Laboratory (1989) (hereinafter "Sambrook et al.").

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MATERIALS AND METHODS FOR EXAMPLES I - III**A. Preparation of Gfi-1 Bacterial Fusion Proteins:**

Expression constructs of Gfi-1 in the pGEX vector (Pharmacia) were used to express

5 glutathione-S-transferase (GST)/Gfi-1 fusion proteins in *Escherichia coli*. Different constructs were designed to express the entire Gfi-1 protein, the zinc finger domain, and the zinc finger domain carrying deletions of individual zinc fingers. Constructs with deletion of

10 individual zinc fingers were generated by overlap extension PCR (1). *E. coli* transformed and selected in ampicillin were grown to log phase and induced with 1 mM isopropyl 13-D-thiogalactopyranoside (IPTG) (Sigma). Three hours following induction, the bacteria were

15 centrifuged and sonicated in cold phosphate buffered saline (PBS). The lysates were then clarified by centrifugation at 15,000 g for 10 minutes at 4°C and were mixed with glutathione-linked agarose beads (Sigma) (1/1000th the volume of the induced bacterial culture).

20 Following a 10 minutes incubation, the beads were washed three times in cold PBS. If the fusion protein was to be eluted, the pelleted beads were washed with 10 mM reduced glutathione (Sigma) in 50 mM Tris-HCl pH 8.0 (2). The liquid was collected and concentrated in a Centriprep-30

25 column (Amicon). Protease inhibitors, Aminoethylbenzene sulfonylflouride (AEBSF) (Calbiochem) and Aprotinin (Sigma)) were added prior to freezing.

B. Gfi-1 DNA Binding and Random Oligonucleotide**30 Selection:**

A 54-base single-stranded DNA oligonucleotide was synthesized to contain a central region of 18 random bases flanked by 18-base regions with defined sequences. One overlapping, complementary oligonucleotide was

35 annealed and extended by AmpliTaq polymerase (Perkin Elmer) to yield a mixture of double-stranded DNA fragments containing >500 copies of each possible

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permutation. This mixture was incubated with GST/Gfi-1 fusion protein bound to beads, prepared as described above, in Binding Buffer (0.2 mg/ml poly dI-dC (Sigma), 0.2 mg/ml acetylated BSA (NEBiolabs), 25 mM Hepes pH 7.5, 100 mM KCl, 0.1 mM ZnSO₄, 10 mM MgCl₂, 0.1% NP-40, 1 mM DTT, 5% glycerol) for 30 minutes. The beads were centrifuged and washed four times with Binding Buffer, then boiled for 5 minutes in H₂O. The oligonucleotide mixture eluted from the beads by boiling was used for PCR amplification using the same amplifying oligonucleotides (3). After 4 rounds of selection/amplification, the PCR products were digested with *Eco*RI and *Hind*III and cloned into pBluescript (Stratagene). Alkaline-lysis prepared plasmid DNA from individual *E. coli* transformants (4) were sequenced (USB Sequenase 2.0 kit).

C. Electro-mobility Shift Assays (EMSA), DNase I Footprinting and DMS Methylation Interference:

Double-stranded DNA fragments of selected Gfi-1 binding sites were produced by PCR amplification of plasmid templates using oligonucleotides end-labeled with [γ 32P]ATP and T4 Polynucleotide Kinase (New England Biolabs). PCR products and Gfi-1 protein were incubated in EMSA Binding Buffer (4 mM Tris-HCl pH 7.5, 80 mM NaCl, 0.5 mM ZnSO₄, 1 mM EDTA, 0.5 mM DTT, 1 μ g poly dI-dC, 1 μ g poly dA-dT (Sigma), 5% glycerol) at 22°C for 30 minutes. Samples were electrophoresed for approximately 3 hours at 100 volts on pre-run, non-denaturing polyacrylamide gels (6% (29:1) Acryl:Bisacrylamide, 0.25xTBE, 5% glycerol) (5). To determine the relative importance of specific bases for Gfi-1 binding, EMSAs were performed with 24 base pair long double stranded mutant oligonucleotides. These oligonucleotides were synthesized *in vitro* and end-labeled using [γ -32P]ATP and T4 polynucleotide kinase.

DNase I footprinting was carried out using a modified published technique (6). PCR products of

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selected Gfi-1 binding sites, 5' labeled with ^{32}P , and recombinant Gfi-1 protein were mixed in 100 μl DNase I Buffer (10 mM Tris-HCl pH 7.8, 10 mM NaCl, 1 mM MgCl_2 , 1 mM CaCl_2 , 0.5 mM ZnSO_4 , 0.5 mM EDTA, 0.1 mM DTT, 0.1 mg/ml acetylated BSA, 2 μg poly dI-dC, 2% polyvinyl alcohol, MW 30-70 kDa (Sigma), 5% glycerol) and incubated at 4°C for 30 minutes. The DNA was then digested for 2 minutes at 4°C by adding approximately 2 μg DNase I (Sigma). The reaction was stopped by adding a 1/1 mixture of phenol:chloroform. The partially digested DNA was ethanol precipitated in the presence of 10 μg glycogen (Boeringer Mannheim) and electrophoresed in a standard 8% polyacrylamide, 8 M urea gel. The fractionated DNA fragments were visualized by autoradiography and phospho-imaging (Fuji) for quantitation.

DMS methylation interference assays were carried out using a modified standard protocol (7). PCR-amplified Gfi-1 binding site oligonucleotides, 5' labeled with ^{32}P , were mixed with 1 μl dimethylsulfate (DMS) in 100 μl DMS Buffer (50 mM Sodium Cacodylate, 1 mM EDTA, 4 μg poly dI-dC) at 22°C for 2 minutes. The methylation reaction was stopped with 25 μl DMS Stop Buffer (0.86 M Tris-HCl pH 7.5, 1.5 M Sodium acetate, 1 M 2-mercaptoethanol). The DNA was then ethanol precipitated, washed twice, and resuspended in Tris-EDTA. The partially methylated DNA was incubated with and without Gfi-1 protein and was subsequently electrophoresed in a nondenaturing polyacrylamide gel. Input DNA (not incubated with Gfi-1) and shifted DNA (Gfi-1 bound) were extracted from crushed gel fragments by incubation in Acrylamide Elution Buffer (0.5 M NH_4OAc , 10 mM MgOAc , 1 mM EDTA, 0.1% sodium dodecyl sulfate (SDS)) for 3 hours at 37°C. The eluted DNA was ethanol precipitated with 10 μg glycogen. The DNA pellet was resuspended in 100 μl 1 M piperidine, heated to 90°C for 30 minutes, ethanol-precipitated and washed three times,

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and electrophoresed in standard 8% polyacrylamide, 8 M urea sequencing gels.

D. Transient Transfection of COS-1 Cells and Gfi-1 EMSA
5 with COS-1 Nuclear Extracts:

COS-I cells (8) were transiently transfected with pCMV5/Gfi-1 or pCMV5 (9) using DEAE Dextran as described for NIH 3T3 cells (10). Forty-eight hours later the transfected cells were washed, scraped and pelleted
10 at 4°C into microcentrifuge tubes. Cell pellets were then resuspended in 10 volumes buffer A (10 mM Hepes-KOH pH 7.9 at 4°C, 1.5 mM MgCl₂, 10 mM KCl, 0.5 mM dithiothreitol (DTT), 0.2 mM AEBSF) for 10 minutes at 4°C, they were then vortexed for 10 seconds and
15 centrifuged in a microfuge for 10 seconds. The pelleted nuclei were resuspended in 2 volumes buffer C (20 mM Hepes-KOH pH 7.9 at 4°C, 420 mM NaCl, 1.5 mM MgCl₂, 0.2 mM EDTA, 0.5 mM DTT, 0.2 mM AEBSF, 25% glycerol) for 20 minutes at 4°C. The resulting lysates were centrifuged
20 at 15,000 g at 4°C for 5 minutes and then were quick frozen and stored in aliquots at -70°C (11). DNA binding for EMSAs was carried out in a final volume of 20 µl using 5 µl of lysate, 1 µg poly dI-dC, 1 µg poly dA-dT, and ³²P-labeled DNA generated by PCR.

25

E. Human Cytomegalovirus (HCMV) Major Immediate Early (MIE) Promoter and Chloramphenicol Acetyl Transferase (CAT) Assay:

The MIE promoter of HCMV (12) contains two
30 putative Gfi-1 binding sites, suggesting that it is regulated by Gfi- 1. To test this hypothesis, both sites (13) in the HCMV-MIE promoter were mutated in the pCMV5 expression vector. The CAT gene was inserted in both wild type and mutant vectors. The wild type and mutant
35 promoter constructs were transfected into NIH 3T3 cells using Lipofectamine (Gibco BRL) according to the procedures recommended by the manufacturer. Forty-eight

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hours later, the cells were washed with PBS, and collected in 0.25 M Tris-HCl pH 7.8. Cell pellets were frozen in an ethanol/dry ice bath, thawed at 37°C for 4 minutes, and vortexed. The lysates generated by
5 repeating this process four times were clarified by centrifugation at 15,000 g at 4°C for 5 minutes. Equivalent amounts of lysates were mixed at 22°C with coenzyme A (CoA) Reaction Mix (80 mM Tris-HCl pH 7.8, 360 µg/µl aqueous chloramphenicol, 67 µM acetyl CoA, 3 µCi
10 [³H]acetyl CoA (Amersham)) in a scintillation vial (35). Scintillation fluid (Econofluor, Dupont) was gently overlayed to fill the vial. ³H counts were measured at successive time points in a scintillation counter (Beckman LS 6000IC). Data presented in Figure 3D
15 represent the average of six independent transfections. Similar data were obtained in three separate experiments.

EXAMPLE I

IDENTIFICATION OF THE Gfi-1 CONSENSUS BINDING SITE

20 Gfi-1 is a 55 kD nuclear protein that binds DNA in a sequence specific manner. The Gfi-1 binding site TAAATCAC(A/T)GCA was defined via random oligonucleotide selection utilizing bacterially expressed GST/Gfi-1 fusion protein. Binding to this site was confirmed by
25 electrophoretic mobility shift assays (EMSA) and DNase I footprinting. DMS methylation interference assay and EMSA with mutant oligonucleotides defined the relative importance of specific bases in the consensus binding site. Potential Gfi-1 binding sites were detected in a
30 large number of eukaryotic promoters/enhancers, including the enhancers of several protooncogenes and cytokine genes and the enhancer of the HCMV-MIE which contains two such sites. HCMV-MIE promoter/CAT reporter constructs, transfected into NIH 3T3 fibroblasts, were repressed by
35 Gfi-1, and the repression was abrogated by mutation of critical residues in the two Gfi-1 binding sites. These results suggest that Gfi-1 may play a role in HCMV

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biology and may contribute to oncogenesis and T cell activation by repressing the expression of genes that inhibit these processes.

A prerequisite for the predicted role of Gfi-1 in transcription is that the Gfi-1 protein is localized in the nucleus. To determine the subcellular localization of Gfi-1 NIH 3T3 cells were transfected with a pCMV5/Gfi-1 expression construct tagged at its N-terminus with a twelve amino acid hemagglutinin (HA) epitope tag. Western blots of total cell lysates from untransfected and transfected cells probed with the HA tag monoclonal antibody 12CA5 revealed that Gfi-1 encodes a 55 kD protein (data not shown). Immunofluorescence staining of transfected and untransfected cells with the HA epitope tag antibody demonstrated that Gfi-1 is a nuclear protein (data not shown).

To determine the putative Gfi-1 binding site, a random oligonucleotide binding/selection strategy was used. The library of oligonucleotides selected by four rounds of Gfi-1 binding was cloned in pBluescript and 96 independent clones were sequenced. Of the sequenced clones, 54 (56%) contained one AATC motif, 35 (36%) contained two AATC motifs and 7 (7%) contained none. Aligning the sequences of the 54 clones that contained only one AATC to this motif (Fig. 2) enabled the determination of the Gfi-1 DNA binding consensus as shown in Figure 1, i.e., $N_1AAATCACN_2GCA$ (Sequence I.D. No. 1, wherein N_1 preferably is T and N_2 preferably is A or T).

To confirm the consensus binding site, the Gfi-1 binding/oligonucleotide selection experiment was repeated starting with oligonucleotides containing an AATC motif flanked by 15 bp random DNA sequences and 18 bp regions with defined sequence. The library of selected oligonucleotides after three rounds of Gfi-1 binding was cloned in pBluescript. Sequencing of 24 clones confirmed the consensus binding site TAAATCACNGCA.

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The homology of selected Gfi-1 binding sites to the consensus ranged from 65% to 98%. This finding tended to indicate a correlation between the relative binding affinity of Gfi-1 to these sites and their
5 homology with the consensus sequence. In order to determine whether this is so, six selected oligonucleotides whose homology to the consensus binding site ranged from 65% to 98% were used to carry out Gfi-1 binding and electrophoretic mobility shift assays. The
10 Gfi-1 protein used in these experiments was expressed as a glutathione-S-transferase (GST) fusion protein in *E. coli*. The results showed that indeed the relative binding affinity of Gfi-1 to individual selected sites is proportional to their homology to the consensus (data not
15 shown).

EXAMPLE II

DNA FOOTPRINT ANALYSIS OF Gfi-1 BINDING SITE

To define the DNA region to which Gfi-1 binds,
20 oligonucleotides representing 4 selected Gfi-1 binding sites with 72, 85, 97 and 98% homology to the consensus were incubated with bacterially expressed GST/Gfi-1 fusion protein. The DNA/protein complexes were digested partially with DNase I and electrophoresed in
25 polyacrylamide/urea sequencing gels. The protected DNA region in each oligonucleotide was assessed by autoradiography. Footprints were obtained only when using oligonucleotides with 97 and 98% homology to the
30 consensus. The results showed a 21 base pair footprint extending 8 bases 5' and 9 bases 3' of the AATC motif in both cases as shown in Fig. 2A.

To define the bases in the Gfi-1 binding site that are in contact with the protein, DMS methylation interference assays were performed using PCR amplified
35 Gfi-1 binding site oligonucleotides and bacterially expressed GST/Gfi-1 fusion protein. The results showed that nine individual bases, when methylated, interfered

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with Gfi-1 binding. See Fig. 2B. Specifically, the methylation of guanines on the complementary strand at positions 6 and 8 greatly impaired protein DNA binding, while methylation of adenines within and around the AATC core and guanines distal to the core had a moderate effect. The footprint and methylation interference data are summarized in Fig. 2C.

Mutations in the Gfi-1 binding site abolish Gfi-1 binding. To confirm the significance of individual bases for Gfi-1 binding, a wild type oligonucleotide (R21) and five mutants (R21 A-E) were synthesized. The single base changes in each mutant are underlined. See Table I.

TABLE I

	123456789101112
R21	CACCACATAAATCACTGCCTATCC (Seq. I.D. No. 6)
R21A	CACCACATAGATCACTGCCTATCC (Seq. I.D. No. 7)
R21B	CACCACATAA <u>CT</u> CACTGCCTATCC (Seq. I.D. No. 8)
R21C	CACCACATAAATA <u>ACT</u> GCCTATCC (Seq. I.D. No. 9)
R21D	CACCACATAAATCA <u>AT</u> GCCTATCC (Seq. I.D. No. 10)
R21E	CACCACATAAATCACT <u>TC</u> CTATCC (Seq. I.D. No. 11)

Using electrophoresis mobility shift assay with recombinant Gfi-1 as the indicator for Gfi-1 binding to these oligonucleotides, the results showed that mutations within the AATC motif greatly decreased or abolished binding, while mutations outside this motif had little effect. See Figs. 2D2 and 2D3. The R21A mutant was still able to bind Gfi-1 although at 5% the level of R21. In agreement with the methylation interference data, a mutation at position 3 prevents binding less efficiently than a mutation at position 4. However, the effect of other mutations could not have been predicted by the methylation interference results alone. Thus, a mutation

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at position 6 (R21C) completely ablated binding while a mutation at position 8 (R21D) had little effect despite the fact that the residues occupying both positions appeared to be equally important by methylation

5 interference.

EMSA experiments were also carried out using the wild type R21 and the R21A mutant oligonucleotide and Gfi-1 protein derived from nuclear extracts of transfected COS-1 cells. The results showed that Gfi-1
10 expressed in COS-1 cells binds the wild type but not the R21 A mutant oligonucleotide (94% and 5% shifted, respectively) which correlates with the EMSA results using bacterially-expressed Gfi-1. See Fig. 2E. Gfi-1 protein expression in transfected but not in
15 nontransfected cells was documented by Western blotting (data not shown).

Many eukaryotic promoters contain potential Gfi-1 binding sites. A computer database search with the Gfi-1 binding consensus revealed potential Gfi-1 binding
20 sites in the promoter region of many genes (Eukaryotic Promoter Database (14)). Table II presents a list of mammalian DNA polymerase II promoters containing potential binding sites whose sequence is $\geq 79\%$ identical to that of the consensus. The list includes several
25 proto-oncogenes and cytokine genes. Subsequently we examined whether the Gfi-1 binding site is consistently near, or overlaps with the binding site(s) of other factor(s) (Transcription Factor Database (15)). Such an association could be interpreted to suggest that Gfi-1
30 binds DNA in concert, or competes with other factor(s) for DNA binding. The results of this analysis revealed that approximately 20% of the putative Gfi-1 binding sites contain GAAATC, the binding site for the histone H4 gene regulatory factor H4TF-I (16).

35

Table II
Identification of Promoters with Potential Gfi-1 Binding Sites

Promoter		% of Consensus	Gfi-1 consensus TAAATCAC _n GCA	Promoter		% of Consensus	Gfi-1 consensus TAAATCAC _n GCA
IL-1 α	Human	80	CAAATCAATAAC	TNF- α	Human	85	CAAATCCCCGCC
IL-1 β	Human	86	TAAATCTGTGTG			80	CAAATCAGTCAG
	Mouse	80	GAAATCAGTTAA		Mouse	82	CTAATCATTGTC
IL-4	Human	87	GAAATCAGACCA		Rabbit	86	GAAATCAGAGGG
	Mouse	87	GAAATCAGTTAA			81	CAAATCCGGGTC
IL-5	Human	89	TCAATCACTGTC		Hamster	86	GAAATCAGAGAG
		85	AAAATCCCTGTT	c-mos	Mouse	90	TAAATCACTCCC
		82	AAAATCAGAAAA	c-abl	Mouse	89	TTAATCACAGTC
IL-6	Human	85	TAAATCTTTGTT	c-erbB2	Human	88	GGAATCACAGGA
IFN α	Human	86	CAAATCTGTGTT	c-myc	Human	90	TAAATCATCGCA
		84	AAAATCTAAGTT	H-myc	Human	86	AAAATCAGGGGA
	Mouse	91	TAAATCAAAGTT	c-H-ras	Human	85	GAAATCAGACCC
IFN γ	Human	79	GAAATCAGTAGT			81	AAAATCAGTAAA
IGF II	Ret	88	AAAATCTGAGCT		House	84	GAAATCAGGCCA
		87	CAAATCAGACCC			81	AAAATCAGTAAA
		84	CAAATCAGACAA	CD8	House	90	CAAATCTCAGTT
		80	AAAATCTTAGGC	Thy-a	House	88	CCAATCACAGGA
		80	TAAATCCTGGGT	Histone H1A	Human	93	AAAATCAAAGCA
	Human	86	TTAATCACGGTT	LTR	HIV	82	CCAATCAGGGAA
CSF-1	Human	89	CAAATCTTAGCA	MIE	HCMV	80	AAAATCAACGGG
		79	GAAATCACCCCTG			79	GAAATCCCCGTG
	Mouse	89	CAAATCTTAGCA	IEgpUS3	HCMV	87	GAAATCACCGTG
G-CSF	Human	79	TAAATCCTGGGA			87	GAAATCCAGTA
		79	GAAATCACCCCTG	early 2.2kb	HCMV	83	CTAATCACGGAC
c-sis	Human	79	TAAATCCTGGGA	early 2.7kb	HCMV	84	AAAATCAGTCCG
	Mouse	79	TAAATCCTGGGA	UL36	HCMV	80	GAAATCGCGGGC
TNF β	Rabbit	84	GAAATCAGGCCA	pp65	HCMV	81	CAAATCCACGCT
TNF β	Human	83	CAAATCATACTT			79	AAAATCGGTGGT
	Rabbit	92	CAAATCAGGGCT				

This list includes selected mammalian promoters retrieved by computer search from the Eukaryotic Promoter Database with the Gfi-1 consensus TAAATCAC(A/T)GCA. All listed potential binding sites have scored $\geq 79\%$ homology to the consensus. This cutoff represents the value for the HCMV MIE promoter binding sites. (Fig.3).

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EXAMPLE IIIGfi-1 REPRESSES THE MIE PROMOTER OF HCMV

Gfi-1 is a transcriptional repressor that
5 downregulates the expression of the MIE promoter of HCMV.
To assess the transcriptional regulatory function of
Gfi-1 in promoters with Gfi-1 binding sites, a
pCMV5/ β -galactosidase expression construct was used to
monitor transfection efficiency. Surprisingly, the
10 expression of β galactosidase in pCMV5/ β -galactosidase
transfected NIH 3T3 cells was downregulated in a Gfi-1
dependent manner (data not shown). To determine the
specificity of this effect the MIE promoter of HCMV in
the pCMV5 vector was examined for the presence of Gfi-1
15 binding sites. This search revealed two putative binding
sites localized within two of the four 18 base pair
repeats of this promoter (12). The two sites were 79%
and 80% homologous to the Gfi-1 binding site consensus
and they were placed at the base and the apex of proposed
20 stem loop structures that may play a role in promoter
function (12). The generation of the Gfi-1 binding sites
within the two 18 bp repeats was due to a divergence of
these repeats from the repeat consensus. See Figs. 3A
and 3B.

25 To confirm and quantitate the Gfi-1 mediated
repression of this promoter, HCMV-MIE promoter/CAT
reporter constructs were cotransfected transiently with a
Gfi-1 expression construct into NIH 3T3 cells. In
addition to the wild type, two mutant reporter constructs
30 were also cotransfected with Gfi-1. See A and B in Fig.
3C. In mutant A, the AATC core of both putative Gfi-1
binding sites was changed into ACTC, while in mutant B
the AATC cores of the two sites were changed into AACT
and AAGT, respectively. The mutant B base changes were
35 designed so that the altered 18 bp repeats would match
the repeat consensus. Based on the data presented in
Fig. 2D1-3, Gfi-1 would not be expected to bind the

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mutant sites. Cotransfection of Gfi-1 and the wild type HCMV-MIE promoter/CAT reporter construct downregulated the activity of the promoter more than four fold. Promoter mutations that abrogate Gfi-1 binding as shown in Fig. 2D1-3 also abrogated Gfi-1 mediated repression. See Fig. 3D.

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15 While certain preferred embodiments of the present invention have been described and specifically exemplified above, it is not intended that the invention be limited to such embodiments. Various modifications may be made to the invention without departing from the scope and spirit thereof as set forth in the following claims.

20

-28-

SEQUENCE LISTING

(1) GENERAL INFORMATION

- 5 (i) APPLICANT: Tsichlis, Philip
Grimes, H. Leighton III
Zweidler-McKay, Patrick
- 10 (ii) TITLE OF THE INVENTION: NUCLEIC ACID MOLECULE
FOR ENHANCING GENE EXPRESSION
- (iii) NUMBER OF SEQUENCES: 14
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(B) STREET: 1601 Market Street, Suite 720
20 (C) CITY: Philadelphia
(D) STATE: Pennsylvania
(E) COUNTRY: USA
(F) ZIP: 19103-2307
- 25 (v) COMPUTER READABLE FORM:
(A) MEDIUM TYPE: Diskette
(B) COMPUTER: IBM Compatible
(C) OPERATING SYSTEM: DOS
(D) SOFTWARE: FastSEQ Version 1.5
- 30 (vi) CURRENT APPLICATION DATA:
(A) APPLICATION NUMBER: not assigned
(B) FILING DATE: 17-JUN-1997
(C) CLASSIFICATION:
- 35 (vii) PRIOR APPLICATION DATA:
(A) APPLICATION NUMBER: US 60/019,808
(B) FILING DATE: 17-JUN-1996
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- 50 (2) INFORMATION FOR SEQ ID NO:1:
- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 12 base pairs
(B) TYPE: nucleic acid
55 (C) STRANDEDNESS: single
(D) TOPOLOGY: linear

-29-

(ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
5 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

10 NAAATCACNG CA
12

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:
15 (A) LENGTH: 12 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

20 (ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
25 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

TAAATCACNG CA
30 12

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:
35 (A) LENGTH: 12 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

40 (ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
(vi) ORIGINAL SOURCE:

45 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

NANNNNACNG CA
50 12

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:
55 (A) LENGTH: 24 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

-30-

(ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
5 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:
10 ANAAAAANAAA TCACNGCATA TGCC
24

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:
15 (A) LENGTH: 33 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
25 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:
ACCATCACCA CATAAATCAC TGCCTATCCT GTG
30 33

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:
35 (A) LENGTH: 24 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
40 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:
CACCACATAA ATCACTGCCT ATCC
24

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:
55 (A) LENGTH: 24 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

-31-

(ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
5 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

10 CACCACATAG ATCACTGCCT ATCC
24

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:
15 (A) LENGTH: 24 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

20 (ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
25 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

CACCACATAA CTCACCTGCCT ATCC
30 24

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:
35 (A) LENGTH: 24 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

40 (ii) MOLECULE TYPE: cDNA
(iii) HYPOTHETICAL: NO
(iv) ANTISENSE: NO
(v) FRAGMENT TYPE:
(vi) ORIGINAL SOURCE:

45 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

CACCACATAA ATAACTGCCT ATCC
24

50 (2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:
55 (A) LENGTH: 24 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

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(ii) MOLECULE TYPE: cDNA
 (iii) HYPOTHETICAL: NO
 (iv) ANTISENSE: NO
 (v) FRAGMENT TYPE:
 5 (vi) ORIGINAL SOURCE:

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:
 CACCACATAA ATCAATGCCT ATCC
 10 24

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:
 15 (A) LENGTH: 24 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA
 (iii) HYPOTHETICAL: NO
 (iv) ANTISENSE: NO
 (v) FRAGMENT TYPE:
 20 (vi) ORIGINAL SOURCE:
 25 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

CACCACATAA ATCACTTCCT ATCC
 24
 30 (2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:
 35 (A) LENGTH: 500 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA
 40 (iii) HYPOTHETICAL: NO
 (iv) ANTISENSE: NO
 (v) FRAGMENT TYPE:
 (vi) ORIGINAL SOURCE:

45 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

	GCCCGCCTGG	CTGACCGCCC	AACGACCCCC	CGGGATTGAC	GTCAATAATG	ACGTATGTTC	60
	CCATAGTAAC	GCCAATAGGG	ACTTTCCATT	GACGTCAATG	GGTGGAGTAT	TTACGGTAAA	120
	CTGCCCACTT	GGCAGTACAT	CAAGTGTATC	ATATGCCAAG	TACGCCCCCT	ATTGACGTCA	180
50	ATGACGGTAA	ATGGCCCGCC	TGGCATTATG	CCCAGTACAT	GACCTTATGG	GACTTTCCTA	240
	CTTGGCAGTA	CATCTACGTA	TTAGTCATCG	CTATTACCAT	GGTGATGCGG	TTTTGGCAGT	300
	ACATCAATGG	GCGTGGATAG	CGGTTTGACT	CACGGGGATT	TCCAAGTCTC	CACCCCATTG	360
	ACGTCAATGG	GAGTTTGTTT	TGGCACCAAA	ATCAACGGGA	CTTTCCAAA	TGTCGTAACA	420
55	ACTCCGCCCC	ATTGACGCAA	ATGGGCGGTA	GGCGTGTACG	GTGGGAGGTC	TATATAAGCA	480
	GAGCTCGTTT	AGTGAACCGT					500

-33-

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

- 5 (A) LENGTH: 500 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

10 (iii) HYPOTHETICAL: NO

(iv) ANTISENSE: NO

(v) FRAGMENT TYPE:

(vi) ORIGINAL SOURCE:

15 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

20 GCCCGCCTGG CTGACCGCCC AACGACCCCC CGGGATTGAC GTCAATAATG ACGTATGTTC 60
CCATAGTAAC GCCAATAGGG ACTTTCCATT GACGTCAATG GGTGGAGTAT TTACGGTAAA 120
CTGCCCCACTT GGCAGTACAT CAAGTGTATC ATATGCCAAG TACGCCCCCT ATTGACGTCA 180
ATGACGGTAA ATGGCCCGCC TGGCATTATG CCCAGTACAT GACCTTATGG GACTTTCCTA 240
CTTGCCAGTA CATCTACGTA TTAGTCATCG CTATTACCAT GGTGATGCGG TTTTGGCAGT 300
ACATCAATGG GCGTGGATAG CGGTTTGACT CACGGGGAGT TCCAAGTCTC CACCCCATTG 360
ACGTCAATGG GAGTTTGTTT TGGCACCAA CTCAACGGGA CTTTCCAAA TGTCGTAACA 420
ACTCCGCCCC ATTGACGCAA ATGGGCGGTA GCGTGTACG GTGGGAGGTC TATATAAGCA 480
25 GAGCTCGTTT AGTGAACCGT 500

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

- 30 (A) LENGTH: 500 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

35 (ii) MOLECULE TYPE: cDNA

(iii) HYPOTHETICAL: NO

(iv) ANTISENSE: NO

(v) FRAGMENT TYPE:

(vi) ORIGINAL SOURCE:

40 (xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

45 GCCCGCCTGG CTGACCGCCC AACGACCCCC CGGGATTGAC GTCAATAATG ACGTATGTTC 60
CCATAGTAAC GCCAATAGGG ACTTTCCATT GACGTCAATG GGTGGAGTAT TTACGGTAAA 120
CTGCCCCACTT GGCAGTACAT CAAGTGTATC ATATGCCAAG TACGCCCCCT ATTGACGTCA 180
ATGACGGTAA ATGGCCCGCC TGGCATTATG CCCAGTACAT GACCTTATGG GACTTTCCTA 240
CTTGCCAGTA CATCTACGTA TTAGTCATCG CTATTACCAT GGTGATGCGG TTTTGGCAGT 300
ACATCAATGG GCGTGGATAG CGGTTTGACT CACGGGACTT TCCAAGTCTC CACCCCATTG 360
ACGTCAATGG GAGTTTGTTT TGGCACCAA ACTAACGGGA CTTTCCAAA TGTCGTAACA 420
50 ACTCCGCCCC ATTGACGCAA ATGGGCGGTA GCGTGTACG GTGGGAGGTC TATATAAGCA 480
GAGCTCGTTT AGTGAACCGT 500

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What is claimed is:

1. An isolated DNA construct comprising at least one mutated binding site for a Gfi-1 transcription repressor, said mutated binding site comprising a mutation which hinders or prevents binding of said Gfi-1 repressor to said site.
2. The DNA construct of claim 1, which is a promoter.
3. The DNA construct of claim 2, wherein said promoter is a mammalian cellular promoter.
4. The DNA construct of claim 2, wherein said promoter is a viral promoter.
5. The DNA construct of claim 4, wherein said promoter is a human cytomegalovirus promoter.
6. The DNA construct of claim 5, which is a cytomegalovirus MIE promoter.
7. The DNA construct of claim 1, wherein said Gfi-1 binding site prior to said mutation is greater than 65% homologous with a sequence comprising TAAATCACNGCA (Sequence I.D. No. 2), wherein N is A or T.
8. The DNA construct of claim 1, wherein said Gfi-1 binding site prior to said mutation is greater than 79% homologous with a sequence comprising TAAACACNGCA (Sequence I.D. No. 2), wherein N is A or T.
9. The DNA construct of claim 1, wherein said Gfi-1 binding site prior to said mutation comprises the sequence N_1 AAATCACN $_2$ GCA (Sequence I.D. No. 1), wherein N_1 and N_2 are any nucleotide, and said mutation is in a

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portion of said binding site comprising the sequence
AATC.

10. The DNA construct of claim 1, wherein said
5 binding site resides within an expression regulatory
segment and said regulatory segment is operatively linked
to a coding segment.

11. The DNA construct of claim 10, wherein the
10 coding segment encodes a gene product selected from the
group consisting of cytokines, interleukins, interferons,
growth factors and proto-oncogenes.

12. An expression regulatory segment
15 comprising at least one copy of a sequence $N_1A-R-CN_2AGCA$
(Sequence I.D. No. 3), wherein N_1 and N_2 are any
nucleotide, and R is a tetranucleotide selected from the
group consisting of:

20 N_3ATC , AN_4TC , AAN_5C , $AATN_6$
 N_3N_4TC , N_3AN_5C , N_3ATN_6 , AN_4N_5C , AN_4TN_6 , AAN_5N_6
 $N_3N_4N_5C$, $N_3N_4TN_6$, $N_3AN_5N_6$, $AN_4N_5N_6$, and $N_3N_4N_5N_6$,

wherein N_3 is G, C or T, or is absent, or is an
oligonucleotide of two or more nucleotides;

25 N_4 is G, C or T, or is absent, or is an oligonucleotide of
two or more nucleotides;

N_5 is A, G or C, or is absent, or is an oligonucleotide of
two or more nucleotides; and

30 N_6 is A, G or C, or is absent, or is an oligonucleotide of
two or more nucleotides.

13. The expression regulatory segment of claim
12, wherein R is selected from the group consisting of
GATC, ACTC and AATA.

35

14. The expression regulatory segment of claim
12, which is a promoter.

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15. The expression regulatory segment of claim 14, wherein said promoter is a mammalian cellular promoter.

5 16. The expression regulatory segment of claim 14, wherein said promoter is a viral promoter.

17. The expression regulatory segment of claim 16, wherein said promoter is a human cytomegalovirus
10 promoter.

18. The expression regulatory segment of claim 17, which is a human cytomegalovirus MIE promoter.

15 19. An expression vector comprising the expression regulatory segment of claim 12 and an operatively positioned insertion site for insertion of a coding segment.

20 20. The expression vector of claim 19, in which is inserted a coding segment selected from the group consisting of cytokines, interleukins, interferons, growth factors and proto-oncogenes.

25 21. An isolated DNA molecule comprising a sequence selected from the group consisting of Sequence I.D. No. 13 and Sequence I.D. No. 14.

22. An expression vector comprising the DNA
30 molecule of claim 21.

23. A method for improving expression of genes regulated by expression regulatory sequences which contain binding sites for a Gfi-1 transcription
35 repressor, which comprises altering the sequence of said binding sites so as to hinder or prevent binding of said

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Gfi-1 transcription repressor to said binding sites,
thereby improving said gene expression.

24. The method of claim 23, wherein said
5 binding sites are altered at a tetranucleotide sequence
contained therein, which is AATC.

25. A method of treating a pathological
condition related to expression of an aberrant gene,
10 which comprises administering to a patient in need of
said treatment a pharmaceutical preparation comprising an
expression vector that includes a non-aberrant
counterpart of said aberrant gene and an operatively
linked promoter comprising at least one mutated binding
15 site for a Gfi-1 transcription repressor, said mutated
binding site comprising a mutation which hinders or
prevents binding of said Gfi-1 repressor to said site.

Fig. 1

A	A	A	A	A	A	C	A	<u>A</u>	<u>A</u>	<u>T</u>	<u>C</u>	A	C	A	G	C	A	T	A	T	G	C	C
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

1 2 3 4 5 6 7 8 9 10 11 12

R21 CACCATATAAATCACTGCCTATCC

R21A CACCATATAAATCACTGCCTATCC

R21B CACCATATAAATCACTGCCTATCC

R21C CACCATATAAATCACTGCCTATCC

R21D CACCATATAAATCACTGCCTATCC

R21E CACCATATAAATCACTGCCTATCC

Fig. 2D1

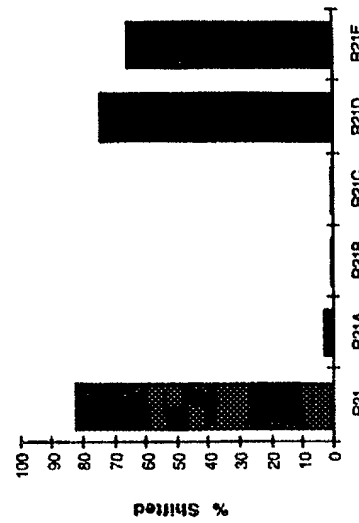
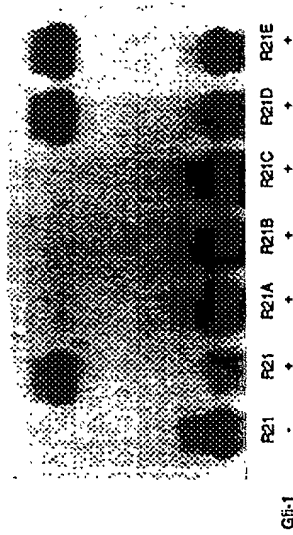


Fig. 2D3

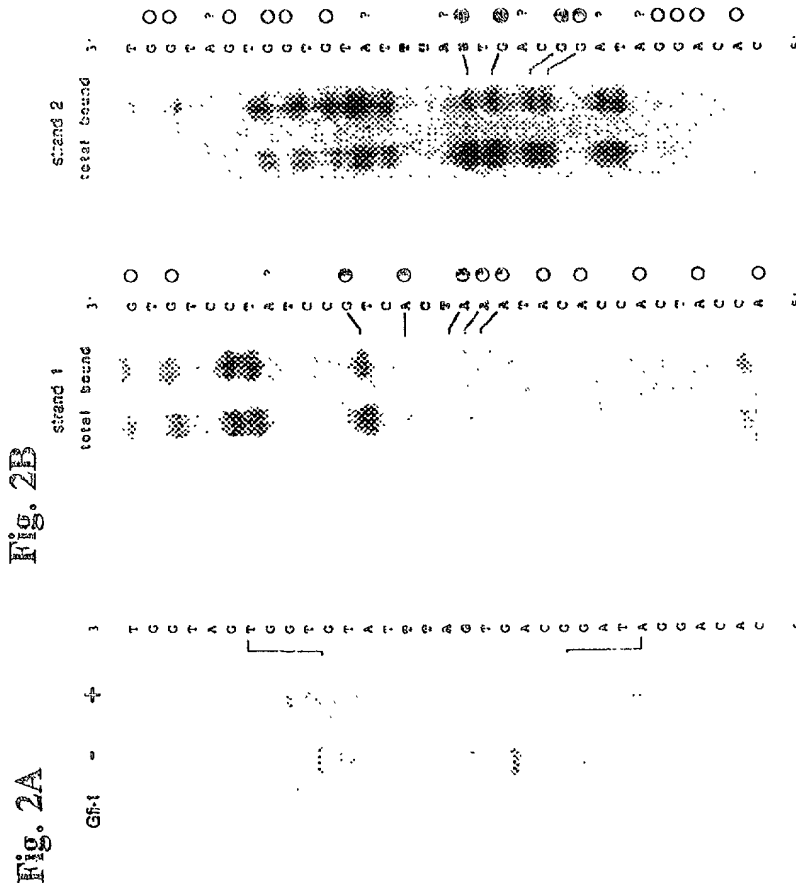
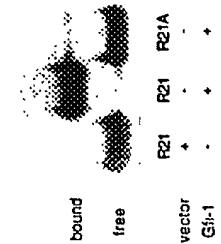


Fig. 2C

1 2 3 4 5 6 7 8 9 10 11 12

...ACCATCACCATATAAATCACTGCCTATCCTGIG...

...TCGTAGTGGTGTATTAGTGACGGATAGGACAC...

Fig. 3A HCMV MIE Promoter

GCCCCGCTGGCTGACCGCCCAACGACCCCCCGCCCATTTGACGTCAATAATG
ACGTATGTTCCCATAGTAACGCCAATAGGGACTTTCATTGACGTCAATG
GGTGGAGTATTTACGGTAACCTGCCCACTTGGCAGTACATCAAGTGATC
ATATGCCAAGTAGCCCCCCTATTGACGTCAATGACGGTAATGGCCCCGCC
TGGCATTATGCCCAGTACATGACCTTATGGGACTTTCCTACTTGGCAGTA
CATCTACGTATTAGTCATCGCTATTACCATGGTGATCGGTTTGGCAGT
ACATCAATGGCGTGGATAGCGGTTTGACTCAGCGGATTTTCAAGTCTC
CACCCCATTGACGTCAATGGGAGTTGTTTGGCACCAAAATCAACGGGA
CTTTCCAAAATGTCGTAACTCACTCGCCCCCATTTGACGCAAAATGGCGGTA
GGCGTGACGGTGGGAGGCTTATATAGCAGAGCTCGTTAGTGAACCGT⁺¹

Fig.3B

Gli-1 consensus TAAATCAC^AGCA
Gli-1 site #1 (-157 to -168) GAAATCCCCGTG
Gli-1 site #2 (-111 to -100) AAAATCAACGGG

Fig. 3C Point Mutations

	Gli-1 site #1	Gli-1 site #2
Wildtype CMV	CACGGGGA ^T TTTC	AAAATCAACGGG
Mutant A	CACGGGGA ^G TTTC	AAAATCAACGGG
Mutant B	CACGGGGA ^C TTTC	AAAATCAACGGG

Fig. 3D

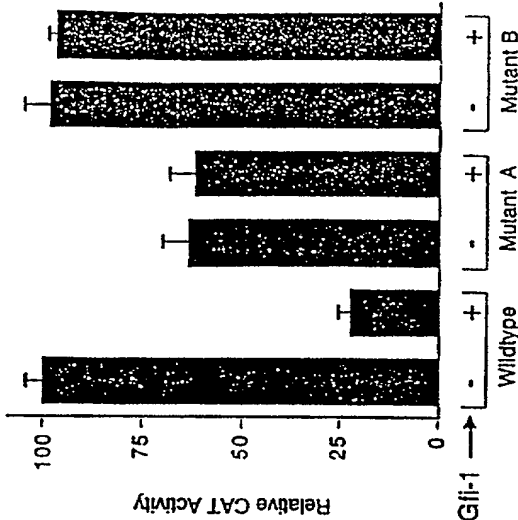


Fig. 4B

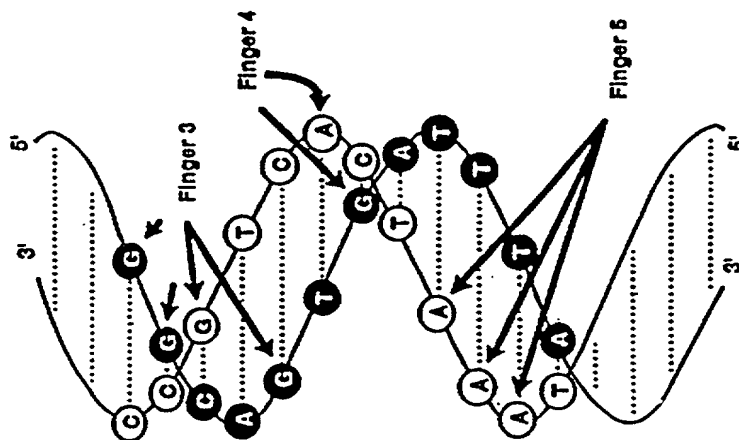
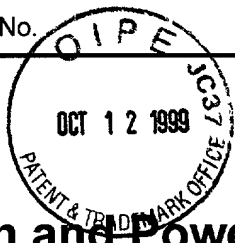


Fig. 4A

	Binding Site	
	Predicted	R21
Gli-1 aa	3'	5'
Finger 1	T G V	- - - - - G G C A G T G A T T T A - - -
Finger 2	H S Q	- - - - - C C G T C A C T A T T T A - - -
Finger 3	R T T	- - - - - G G T C A C T A T T T A - - -
Finger 4	Q D K	- - - - - A C G T A C T A T T T A - - -
Finger 5	Q N T	- - - - - A C G T A C T A T T T A - - -
Finger 6	R D R	- - - - - G G T C A C T A T T T A - - -



Docket No.
FCCC 96-11

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on June 17, 1997 as United States Application No. or PCT International Application Number PCT/US97/10486 and was amended on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Not Claimed
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/>

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

60/019,808	June 17, 1996
_____ (Application Serial No.)	_____ (Filing Date)
_____ (Application Serial No.)	_____ (Filing Date)
_____ (Application Serial No.)	_____ (Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)
_____ (Application Serial No.)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

Louis M. Heidelberger, Reg. No. 27,899; John W. Goldschmidt, Jr., Reg. No. 34,828; Daniel H. Golub, Reg. No. 33,701; William J. McNichol, Jr., Reg. No. 31,179; R. Anthony Diehl, Reg. No. 38,432; Maryellen Feehery, Reg. No. P-44,677; Alison B. Weisberg, Reg. No. P-45,206; Ethan D. Civan, Reg. No. P-44,459; Nanda P.B.A. Kumar, Reg. No. P-44,853; Matthew J. Esserman, Reg. No. 41,536; Frederick H. Colen, Reg. No. 28,061; Arland T. Stein, Reg. No. 25,062; W. Scott Railton, Reg. No. 23,039; Gene A. Tabachnick, Reg. No. 33,801; Raymond A. Miller, Reg. No. 42,891; Maria N. Rullo, Reg. No. 37,433; Barry J. Coyne Reg. No. 43,566; Ayla A. Lari, Reg. No. 43,739; Kirsten R. Rydstrom, Reg. No. 38,603; Paul D. Bangor, Jr., Reg. No. 34,768; Cheryl L. Gastineau, Reg. No. 39,469; Ian K. Samways, Reg. No. 36,664; Charles H. Dougherty, Jr., Reg. No. 42,494; Mary E. Buckles, Reg. No. 31,907 and Ronald J. Campbell, Reg. No. 33,842.

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Reed Smith Shaw & McClay LLP
2500 One Liberty Place, 1650 Market Street
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Full name of sole or first inventor Philip N. Tschlis	
Sole or first inventor's signature <i>Philip N. Tschlis</i>	Date 10/6/99
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Full name of second inventor, if any Leighton H. Grimes, III	
Second inventor's signature	Date
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Citizenship USA	
Post Office Address Same as Above	

Full name of third inventor, if any

Patrick Zweidler-McKay

Third inventor's signature

Date

Residence

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USA

Post Office Address

Same as Above

Full name of fourth inventor, if any

Fourth inventor's signature

Date

Residence

Citizenship

Post Office Address

Full name of fifth inventor, if any

Fifth inventor's signature

Date

Residence

Citizenship

Post Office Address

Full name of sixth inventor, if any

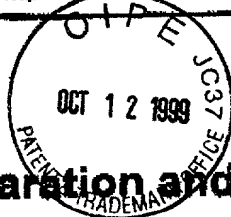
Sixth inventor's signature

Date

Residence

Citizenship

Post Office Address



Docket No.
PCCC 96-11

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on June 17, 1997 as United States Application No. or PCT International
Application Number PCT/US97/10486
and was amended on _____

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

60/019,808	June 17, 1996
(Application Serial No.)	(Filing Date)
_____	_____
(Application Serial No.)	(Filing Date)
_____	_____
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

_____	_____	_____
(Application Serial No.)	(Filing Date)	(Status)
		(patented, pending, abandoned)
_____	_____	_____
(Application Serial No.)	(Filing Date)	(Status)
		(patented, pending, abandoned)
_____	_____	_____
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Tel: 215-241-7950; Fax: 215-851-1420

Full name of sole or first inventor	Philip N. Tsichlis
Sole or first inventor's signature	<i>Philip N. Tsichlis</i> Date 10/6/99
Residence	50 Brentwood Ave, Willow Grove, PA 19090
Citizenship	USA
Post Office Address	Same as Above

Full name of second inventor, if any	Leighton H. Grimes, III
Second inventor's signature	<i>Leighton H. Grimes, III</i> Date 10/12/99
Residence	1576 Cherokee Rd. #4, Louisville, KY 40205
Citizenship	USA
Post Office Address	Same as Above

Full name of third inventor, if any

Patrick Zweidler-McKay

Third inventor's signature

Date

Residence

66 Cameron Avenue, Somerville, MA 02144-2404

Citizenship

USA

Post Office Address

Same as Above

Full name of fourth inventor, if any

Fourth inventor's signature

Date

Residence

Citizenship

Post Office Address

Full name of fifth inventor, if any

Fifth inventor's signature

Date

Residence

Citizenship

Post Office Address

Full name of sixth inventor, if any

Sixth inventor's signature

Date

Residence

Citizenship

Post Office Address

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UNITED STATES PATENT AND TRADEMARK OFFICE

Express Mail Label No.

10-213-920-0010

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Page 1 of 4

OCT 12 1999

Docket No.

FCCC 96-11

Declaration and Power of Attorney For Patent Application

English Language Declaration

As a below named inventor, I hereby declare that:

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(check one)

☐ is attached hereto.

☒ was filed on June 17, 1997 as United States Application No. or PCT International Application Number PCT/US97/10480 and was amended on _____

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Prior Foreign Application(s)

Priority Not Claimed

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

(Number)

(Country)

(Day/Month/Year Filed)

☐

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TODD OWEN COUNSEL

10-210-920-5610

OCT 11 1999

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P.05

Page 2 of 4

I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

<u>60/019,808</u>	<u>June 17, 1996</u>
(Application Serial No.)	(Filing Date)
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(Application Serial No.)	(Filing Date)	(Status)
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Sole or first inventor's signature	Date
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Page 4 of 4

Full name of third inventor, if any

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Fourth inventor's signature

Date

Residence

Citizenship

Post Office Address

Full name of fifth inventor, if any

Fifth inventor's signature

Date

Residence

Citizenship

Post Office Address

Full name of sixth inventor, if any

Sixth inventor's signature

Date

Residence

Citizenship

Post Office Address